Literature review for use of FRP in Civil Engineering

Dr. Sunilkumar Patil[1], Ankita Vilas Dhongade[2]

[1]*Head of the Civil Engineering Department, Walchand Institute of Technology, Solapur, Maharashtra, India*
[2]*M.E. Structures, Walchand Institute of Technology, Solapur, Maharashtra, India*

Abstract - *This paper states about the history of the fiber reinforced concrete also the application-based research since 1930 when the first natural fiber composite material appeared. The paper also tells us about the various composite material and their application in the construction in early 1900 century. The first man-made fibers used in composites were glass fibers. The discussion is also done on the types of the fiber reinforced polymer such as glass fiber, carbon fiber. The literature studied those are, behavior of circularized and FRP wrapping, experimental and numerical study of strengthening non-ductile RC columns with and without lap splice by CFRP jacketing, shear capacity of pre-cracked reinforced concrete shear beams with externally bonded bi-directional CFRP strips.*

Key Words: **FRP, CFRP, SFRP, Jacketing, Strengthening of RC column and beam,**

1.INTRODUCTION

Composites have been used throughout the history of building construction. Mud and straw were used to make adobe bricks or mass walls. Lime plaster was traditionally reinforced with straw or animal hair. Wood is a natural Fiber-Reinforced Polymer that has been widely used in construction. Wrought iron is a composite material: the parent metal is infused with slag filaments, principally iron silicate. In the 20th century, synthetic adhesives facilitated development of plywood and glulam beams, which improved the mechanical properties of timber. Natural fiber composite materials first appeared around 1930, although they never entered building construction. Henry Ford changed his mind only at the last minute to make the Model A with mild steel rather than natural fiber composite. The notorious East German Trabant had cotton fiber composite body panels. The first man-made fibers used in composites were glass fibers. Unsaturated polyester production after the war enabled Glass Reinforced Polyester (GRP) to find an immediate application in boat building. Carbon fiber production began in the late 1950s and was used, though not widely. GRP moved into building construction during the 1960s, finding applications in cladding and bespoke ornament. Today, each of these fibers is used widely in industry for any applications that require plastics with specific strength or elastic qualities. The application of FRP's is becoming increasingly common in the construction of new structures (e.g. bridge decks, and towers). However, since deterioration and functional deficiency of existing civil infrastructures represent one of the struggling challenges of the world of today, these high-performance materials are also vastly used for repair and strengthening of existing structures. Therefore, many researchers move towards the retrofitting work with FRP. Fiber-reinforced plastic (FRP) (also called fiber-reinforced polymer, or fiber-reinforced plastic) is a composite material made of a polymer matrix reinforced with fibers. The fibers are usually glass (in fiberglass), carbon (in carbon-fiber-reinforced polymer), aramid, or basalt. Rarely, other fibers such as paper, wood, or asbestos have been used

2. TYPES OF FRP

2.1 Glass Fiber

"Fiberglass reinforced plastics" or commonly referred to simply as fiberglass, use textile grade glass fibers. These textile fibers are different from other forms of glass fibers used to deliberately trap air, for insulating applications. Textile glass fibers begin as varying combinations of SiO_2, Al_2O_3, B_2O_3, CaO, or MgO in powder form. These mixtures are then heated through direct melting to temperatures around 1300 degrees Celsius, after which dies are used to extrude filaments of glass fiber in diameter ranging from 9 to 17 µm. These threads are then commonly used for woven reinforcing glass fabrics and mats, and in spray applications.

2.2 Carbon Fiber

Carbon fibers are created when polyacrylonitrile fibers (PAN), Pitch resins, or Rayon are carbonized (through oxidation and thermal pyrolysis) at high temperatures. Through further processes of graphitizing or stretching the fibers strength or elasticity can be enhanced respectively. Carbon fibers are manufactured in diameters analogous to glass fibers with diameters ranging from 4 to 17 µm. These fibers wound into larger threads for transportation and further production processes. Further production processes include weaving or braiding into carbon fabrics, cloths and mats that can then be used in actual reinforcements.

2.3 Aramid Fiber

Aramid fibers are most known as Kevlar, Nomex and Technora. Aramids are generally prepared by the reaction between an amine group and a carboxylic acid halide group (aramid); commonly this occurs when an aromatic polyamide is spun from a liquid concentration of sulphuric acid into a crystallized fiber. Fibers are then spun into larger threads in order to weave into large ropes or woven fabrics (Aramid). Aramid fibers are manufactured with varying grades based on varying qualities for strength and rigidity, so that the material can be somewhat tailored to specific design needs concerns, such as cutting the tough material during manufacture.

3. NECESSITY OF FRP

With structures becoming old and the increasing bar corrosion, old buildings have started to demand additional retrofits to increase their durability and life. To meet up the requirements new innovative materials and technologies in construction industry has started to make its way. Engineers throughout the world have used Fiber Reinforced Polymer (FRP) to solve their structural problems in an efficient and economical manner. In the field of civil engineering, most of the use of FRP is confined to repairing and strengthening of structures. Use of FRP for confinement has proved to be effective retrofitting and strengthening application. The confinement in seismically active regions has proved to be one of the early applications of FRP materials in infrastructure applications. Confinement may be beneficial in non-seismic zones too, where, for instance, survivability of explosive attacks is required, or the axial load capacity of a column needs to be increased due to higher vertical loads. Hence, FRP composites are finding ways to prove effective. Like other materials, FRP also has its limitations. There are several situations in which a civil structure would require strengthening or rehabilitation due to lack of strength, stiffness, ductility and durability. Some common situations where a structure needs strengthening during its lifespan are: 1) Seismic retrofit according to current code requirements. 2) Upgraded loading requirements, damage by accidents and environmental conditions. Initial design flaw. Change of usage. Depending on the desired properties, usage and level of damage in structural members, these can be repaired and strengthened by several widely used methods. In this dissertation, an experimental study will be carried out for finding the increase in strength of RCC beams and columns with CFRP wrapping.

4. CIVIL ENGG APPLICATION OF FRP

FRP can be applied to strengthen the beams, columns, and slabs of buildings and bridges. It is possible to increase the strength of structural members even after they have been severely damaged due to loading conditions. In the case of damaged reinforced concrete members, this would first require the repair of the member by removing loose debris and filling in cavities and cracks with mortar or epoxy resin. Once the member is repaired, strengthening can be achieved through wet, hand lay-up of impregnating the sheets with epoxy resin then applying them to the cleaned and prepared surfaces of the member. Two techniques are typically adopted for the strengthening of beams, relating to the strength enhancement desired: flexural strengthening or shear strengthening. In many cases it may be necessary to provide both strength enhancements. For the flexural strengthening of a beam, FRP sheets or plates are applied to the tension face of the member (the bottom face for a simply supported member with applied top loading or gravity loading). Principal tensile fibers are oriented in the beam longitudinal axis, like its internal flexural steel reinforcement. This increases the beam strength and its stiffness (load required to cause unit deflection), however decreases the deflection capacity and ductility. For the shear strengthening of a beam, the FRP is applied on the web (sides) of a member with fibers-oriented transverse to the beam's longitudinal axis. Resisting of shear forces is achieved in a similar manner as internal steel stirrups, by bridging shear cracks that form under applied loading. FRP can be applied in several configurations, depending on the exposed faces of the member and the degree of strengthening desired, this includes side bonding, U-wraps (U-jackets), and closed wraps (complete wraps). Side bonding involves applying FRP to the sides of the beam only. It provides the least amount of shear strengthening due to failures caused by de-bonding from the concrete surface at the FRP free edges. For U-wraps, the FRP is applied continuously in a 'U' shape around the sides and bottom (tension) face of the beam. If all faces of a beam are accessible, the use of closed wraps is desirable as they provide the most strength enhancement. Closed wrapping involves applying FRP around the entire perimeter of the member, such that there are no free ends and the typical failure mode is rupture of the fibers. For all wrap configurations, the FRP can be applied along the length of the member as a continuous sheet or as discrete strips, having a predefined minimum width and spacing. Slabs may be strengthened by applying FRP strips at their bottom (tension) face. This will result in better flexural performance, since the tensile resistance of the slabs is supplemented by the tensile strength of FRP. In the case of beams and slabs, the effectiveness of FRP strengthening depends on the performance of the resin chosen for bonding. This is particularly an issue for shear strengthening using side bonding or U-wraps. Columns are typically wrapped with FRP around their perimeter, as with closed or complete wrapping. This not only results in higher shear resistance, but more crucial for column design, it results in increased compressive strength under axial loading. The FRP wrap works by restraining the lateral expansion of the column, which can enhance confinement in a similar manner as spiral reinforcement does for the column core.

5. LITERATURE REVIEW

The following researchers have carried out the experimental study related to the dissertation topic.

5.1 Ahmed Ghobarah and A. Said (2001)

The experimental study performed by the author which gives the result about shear strengthening of beam and column joints. Different fiber-wrap rehabilitation schemes were applied to the joint panel with the objective of upgrading the shear strength of the joint. They have given the comparison between the performance of original specimens and rehabilitated ones shows that the GFRP jacket could increase the shear resistance of the joint and enhancing the performance of the connection from a ductility point of view. They have observed that Shear mode of failure transferred to flexural hinging of the beam, which is a ductile mode of failure.

5.2 Kumar et al (2007)

The author established that retrofitting of previously damaged columns with CFRP jackets resulted in improvements in strength and ductility. The level of improvement, however, would be dependent on the damage experienced by the column prior to retrofitting. High axial load resulted inconsiderable reduction in the ductility and energy dissipation capacity of the columns, with the work index indicative of energy dissipation capacity being the worst affected parameter; and ductility improvement in square columns with lap splices as a result of CFRP retrofitting were significantly lower than that for comparable circular columns due to more efficient confinement mechanism in circular shapes. The CFRP retrofitting technique was found to be effective in enhancing the seismic resistance of the columns and resulted in more stable hysteresis cures with lower stiffness and strength degradations as compared with the un retrofitted columns

5.3 K. Olivova and J. Bilick (2008)

The literature given by author gives experimental study on the structural behavior of reinforced concrete columns strengthened with carbon fiber sheets and strips in pre-cut grooves. The main tasks of these experiments were conducted to investigate the effects of additional strengthening of reinforced columns due to carbon fiber. They found that the results obtained from the numerical analysis (FEM–ATENA program) were approximately 20% higher than the theoretical analysis results (interaction curves) for all the tested column specimens. Also, the results obtained from the experiment were approximately 25 – 35 % higher than the theoretical analysis results. They observed the results of the strengthening technique proposed by the near surface mounted (NSM) technique are promising for increasing the load-carrying capacity of concrete columns failing in bending.

5.4 K.P. Jaya and Jessy Mathai (2012)

The experimental work to study the increase in ductility and energy absorption capacity of RC beam-column when strengthened by both GFRP and CFRP Jacket. The specimens were tested under a constant axial load and reversed cyclic lateral loading. The column specimens wrapped with two layers, four layers and six layers of GFRP shows 8%, 28% and 32% increase in the load carrying capacity respectively compared to the specimen without wrapping. The specimen jacketed with 6 layers of GFRP has the highest load carrying capacity and there is 32% increase in the strength compared with the specimen without GFRP wrapping. The column specimens wrapped with two layers, four layers and six layers of GFRP shows 25%, 54% and 70% increase in ductility respectively compared to the specimen without wrapping.

5.5 Thamer Kubat, Riadh Al- Mahaidi, Ahmad Shayan(2016)

In this literature CFRP confinement of circular concrete columns affected by alkali-aggregate is given. AAR cause expansion and cracking in concrete, which adversely affect the mechanical properties of concrete, leading to decrease the service life of structures. This study shows the result that CFRP increased the strength and strain capacity of confined columns to unconfined columns. Larger number CFRP layers also increased the capacity of the affected columns.

5.6 Pranay Ranjan and Poonam Dhiman (2016)

The author designed RC, FRP and SFRC Jacketing of failed columns of an existing building and to compare suitability of these three methods of retrofitting. The author also explained the design procedure of Reinforced Concrete, Carbon Fiber Reinforced Polymer Jacketing and Steel Fiber Reinforced Polymer Jacketing for strengthening an existing column. The comparative study of all methods is given in this paper. In RC Jacketing, sizes of the sections are increased, and the free available usable space becomes less, and huge dead mass is added. Jacketing with RC plates drilling of holes in existing column, slab, beams and footings are required which cause further damage to the structure. Confinement by FRP Jackets enhanced the performance of concrete columns. FRP Jacketing offers several advantages over the RC and SFRC Jacketing but it is slightly expensive.

5.7 Mohmmad R. Irshidat, Mohmmad H. Al-Saleh (2017)

This paper presents the influence of using carbon nanotubes (CNTs) on flexural strength recovery of heat damaged RC beams with carbon fiber reinforced polymer (CFRP) composites. The samples were casted and heated up to 500^0 to 600^0 and repaired. The results were analyzed through load-deflection curves, crack patterns, mode of failure And SEM (Scanning Electron Microscopy Imaging) analysis. Using epoxy resin modified with CNTs the strengthening capacity of heat damaged beam. The results shows that CFRP confinement enhanced the ultimate load carrying capacities and stiffness by (111%,81%) and (75%,56%) of values of unheated beam.

5.8 Mohmmad T. Jameel,M. Neaz Sheikh, Mohmmad N.S. Hadi(2017)

The Behavior of Circularized and FRP wrapped hollow concrete specimens under axial compression load has been studied in this literature. The test results demonstrate that circularization of hollow specimen is similar to the circularization of solid specimen reduces the stress concentration at the corners and enhances the ultimate load carrying capacity and ductility. The contribution to the ultimate axial stress from circularization is significantly more for both hollow and solid concrete specimens than from rounding the corners. A simplified theoretical model was developed to predict the axial load of CFRP confined square and circularized solid and hollow specimens

6. CONCLUSIONS

By going through the research, it is observed that, there is not any procedural data or standard code available in India for application of FRP. That is why the research and application is followed by the literature available on the FRP. By considering the importance of past literature practical and analytical study is done on the FRP.

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BIOGRAPHIES

1)Dr. Patil Sunilkumar S.
Professor and Head,
Civil Engineering Department,Walchand Institute of Technology, Solapur Chairman, Institution of Engineers India, Solapur Centre(IEI-SLC) -2018 to 2020, Indian Society of Structural Engineers, Solapur,
Email: patilss1962@gmail.com,
sspatil1962@rediffmail.com,
headcivilwit@gmail.com,
sspatil@witsolapur.org
Website: www.witsolapur.org

2) Ankita Vilas Dhongade.
Pursuing M.E. (Structural Engineering),
Walchand Institute of technology, Solapur.